THE DISTRIBUTION OF THE DIATOM

Gomphonema geminata

IN VANCOUVER ISLAND STREAMS

WORK TERM REPORT

in partial fulfillment of the requirements
of the Biology Co-Op Program
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SUMMARY

The growth of the diatom *Gomphonema geminata* in Vancouver Island streams was investigated from May 1, 1991 to July 31, 1991. It was found to be growing in six streams: the Puntledge, Little Qualicum, Heber, Gold, Oyster and Stamp/Somass Rivers, all located in the central portion of Vancouver Island.

Gomphonema geminata appeared to prefer water depths between 0.1 m and 2.0 m, stable substrates, increasing water temperatures and high light intensities. Streams which were buffered against winter floods appeared to have a more extensive coverage of *G. geminata*. Ortho-phosphate concentrations were found to be consistently low and could not be related to growth.

High densities of chironomid larvae and, in some cases, mayfly larvae were found within the algal mat suggesting a favourable habitat. Decreases in caddisfly larvae and stonefly larvae numbers in affected reaches suggested an adverse effect.

Salmonid parr and fry appeared to avoid areas of dense growth while they were abundant in nonaffected areas of the same stream.

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1.0 INTRODUCTION

During a field investigation in late August, 1988, a dense algal mat was discovered at the confluence of the Gold and Heber Rivers (see Figure 1). The mat was identified as being diamataceous and dominated by *Gomphonema geminata*. Further investigation showed small pockets of the same growth in the Gold River just upstream of its confluence with the Heber and in upstream areas of the Heber itself. At the time this was the only known occurence of *G. geminata* on Vancouver Island (Deniseger, 1990). Subsequent monitoring of the Heber River during the summer and fall of 1989 documented the growth of an algal mat several centimeters thick which again was dominated by *G. geminata*.

In June, 1990, a growth similar to that in the Heber was found in the lower reaches of the Oyster River (see Figure 1) and in September, 1990 an algal growth dominated by *G. geminata* was identified in the Stamp River (see Figure 1). In addition, there were also several undocumented reports from rivers including the Nahmint and Burman (see Figure 1) during this same period. The algal mats in the Oyster and Heber began to deteriorate in early October as a result of decreasing temperatures and light levels and increasing flows.

By mid July, 1991, *G. geminata* had been identified in six Vancouver Island streams, namely the Puntledge, Heber, Gold, Little Qualicum, Oyster and Somass. Prior to 1988 the only documented occurrence of this diatom in British Columbia was in the Fulton River which drains into Babine Lake, east of Smithers.

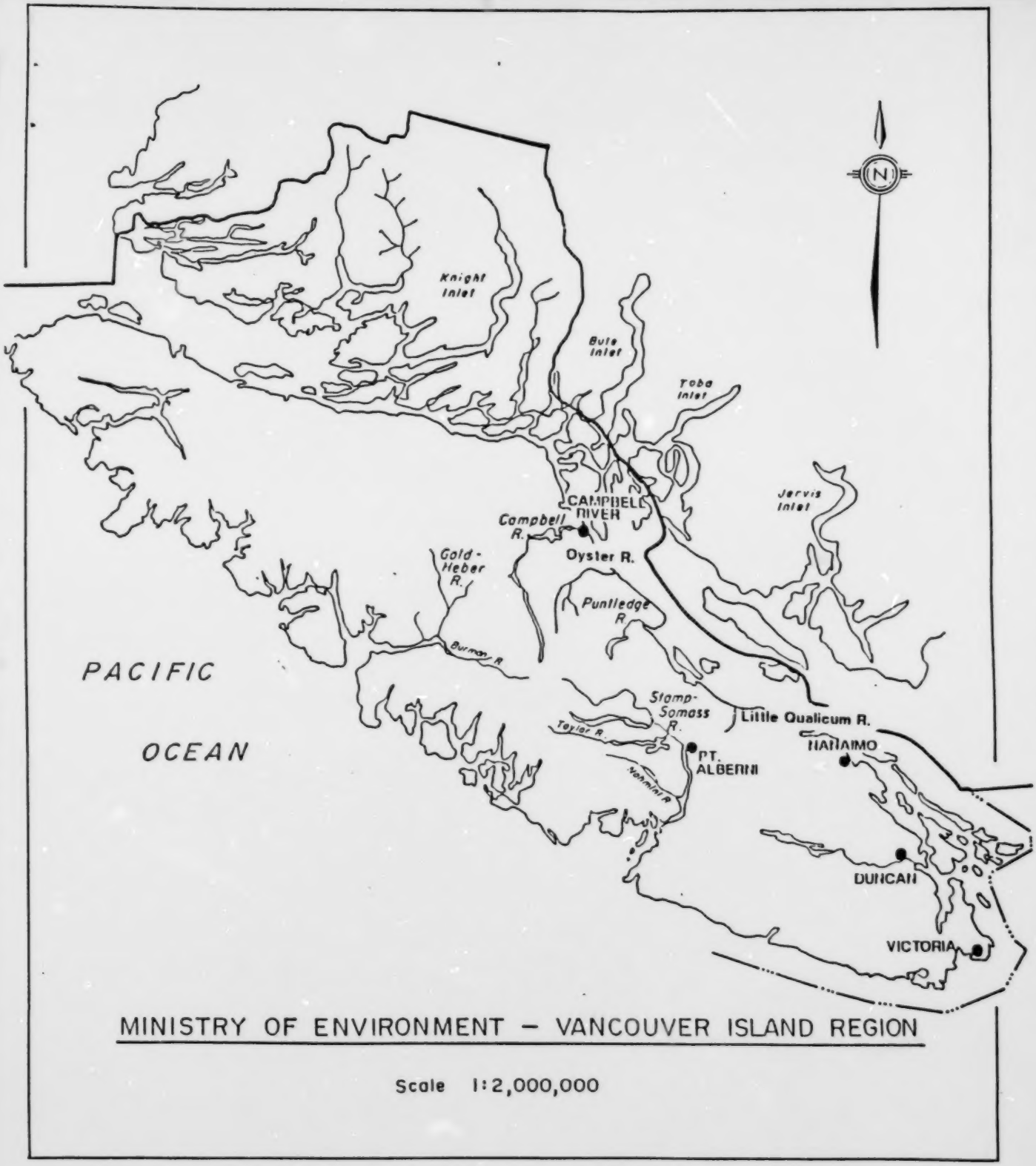

Figure 1: Vancouver Island streams containing *Gomphonema geminata*.

The overall appearance of the algal growth resembles a brownish gold mat which can be found in all areas of a stream where excessive flow or depth will not limit its growth. Once established, the mat is aesthetically displeasing and may lower the recreational value of a stream. Reductions in water quality are also possible, as indicated by complaints regarding the taste of drinking water in Gold River. Reports of eye irritations by swimmers in affected streams suggest that individual frustules in suspension may cause irritations when in direct contact with the eye. It is also possible that fish gills would be susceptible to the same irritations. In addition, reductions in available salmonid rearing habitat and possible decreases in dissolved oxygen levels during fall die off may lower the fisheries value of streams which host this diatom. The fall die off has also resulted in the blockage of intake screens at the Oyster River spawning channel (see Figure 6).

The purpose of this report is to document the streams on Vancouver Island affected by *G. geminata*, follow growth patterns to July 31, 1991, and assess its impact in terms of recreational and fisheries values. Little work on *G.geminata* has been published and therefore work done on other periphytic diatoms is applied where practical.

2.0 PHYSICAL DESCRIPTION AND HABITAT

Species of algae belonging to the genus *Gomphonema* are epiphytic diatoms which are attached to a stalk like secretion of polysaccharide matrix (Bold & Wynne, 1978). *G. geminata* is a pennate diatom which has the shape of a violin case in the valve view and is funnel shaped in the girdle view (see Appendix I, No. 1). The vegetative cell grows at the terminal end of the stalk (see Appendix I, No. 2), which is sometimes forked.

When seen growing in streams the stalk is white in appearance and the vegetative cell is gold to brown in colour. *G. geminata* initially appears in small tufts on substrate larger than small cobble (see Appendix VI, No. 3) and can develop into a mat covering an entire stream bed (see Appendix V, No. 3), except where excessive flows and depths (> 2.0 m) tend to limit its growth.

The growth of periphytic algae is influenced by environmental factors such as water temperature, light exposure, physical abrasion, nutrient levels and invertebrate grazing (Rounick & Gregory, 1981). Work done by Antoine and Benson-Evans (1986) in Wales, U.K. indicated that high light intensities, high temperatures and low flows are favourable to the growth and expansion of *G. geminata*. Other work (Bothwell, 1989) has shown that low temperatures slow the growth of periphytic diatoms.

Diatoms also respond positively to nutrient additions. Studies have suggested that the growth of periphytic algae increased with NO_3 plus PO_4 additions and PO_4 only additions (Winterbourn, 1990; Bothwell, 1989; Pringle & Bowers, 1984).

Although the diatoms do respond positively to PO_4 additions, Bothwell (1989) has shown that growth rates saturate at very low concentrations (< 1.0 ppb).

3.0 STUDY AREAS

3.1 Gold and Heber Rivers

The Gold River originates in the Tyee/Horseshoe Mountain drainage and flows approximately 46 km from Gold Lake to Muchalet Inlet with a drainage of 825 km^2. The Heber River originates in the Mt. Heber/Mt. Judson drainage and flows approximately 40 km before meeting the Gold within the village of Gold River (see Figure 2). The system has high recreational values and supports a popular sport fishery with runs of chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), and steelhead (*O. mykiss*). There are also a number of swimming areas popular with the people of Gold River.

Sample sites on the Gold and Heber Rivers are outlined in Deniseger and Erickson (1990).

3.2 Puntledge River

The Puntledge River flows northeast for 14.2 km into the Courtenay River and is fed by Comox Lake, the Browns River, the Tsolum River and Morrison Creek. Its drainage area is 518 km^2. The system supports runs of chinook, coho, chum (*O. nerka*), and pink (*O. gorbushca*) salmon , as well as steelhead. There are two sets of falls, located at 6.4 km and 8.0 km, which are passable depending on flow levels. Most spawning areas are located in the lower reaches (0 - 6.4 km). The Puntledge River Hatchery has two facility sites located approximately 4.0 km and 11.3 km from its confluence with the Courtenay. In addition to a sport fishery, the

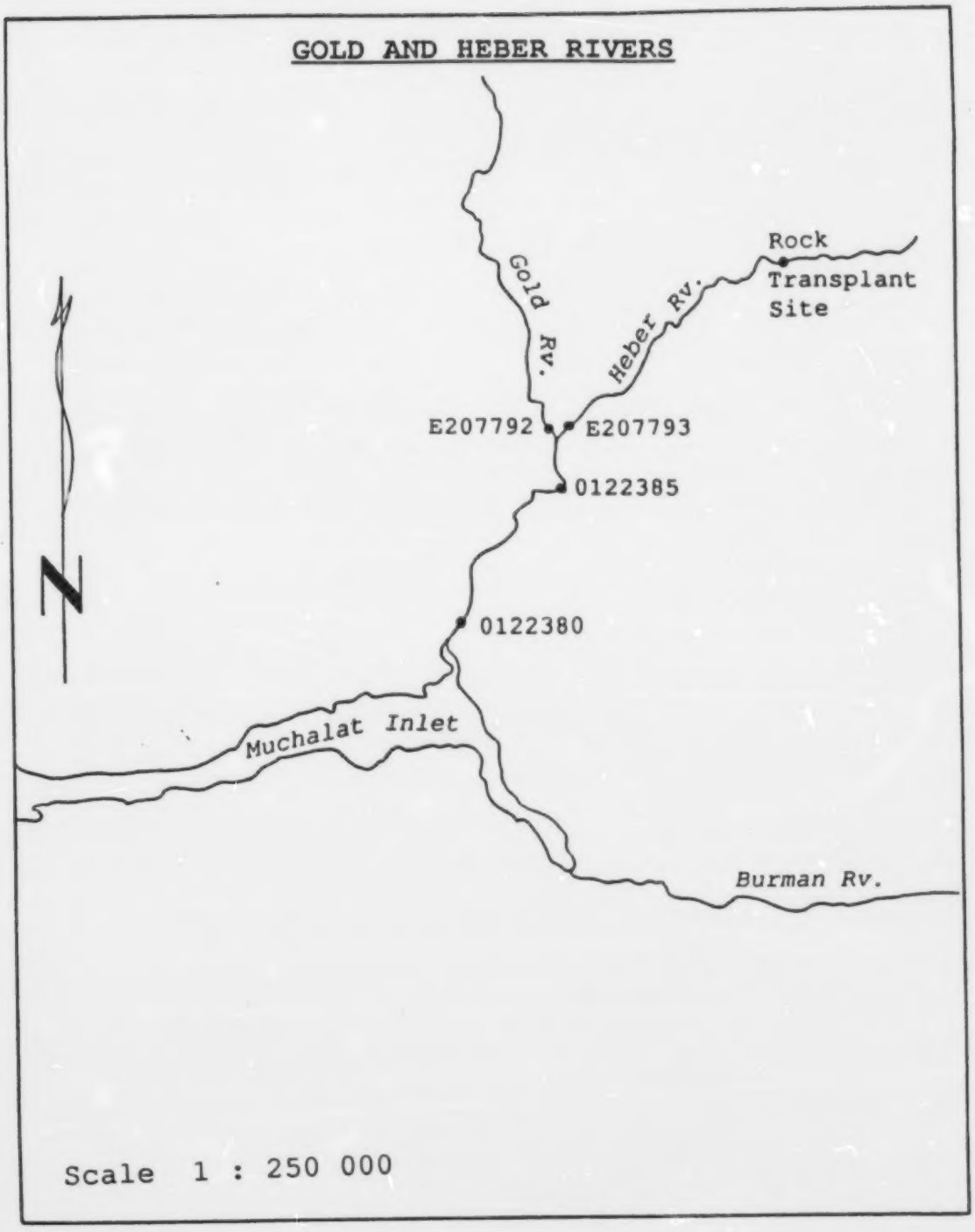

Figure 2: Map of the Gold and Heber River sample sites.

Puntledge also has a number of swimming areas giving it a significant recreational value.

The sampling site on the Puntledge is located at the logging road bridge, approximately 8 km from the mouth of the river (see Figure 3).

3.3 Somass River

The Somass River flows southeast and south into Alberni Inlet (see Figure 4). It is fed by the Sproat Lake - Sproat River system, the Great Central Lake - Stamp River system and an additional 320 km of smaller tributaries with a drainage area of 1284.6 km^2. The Somass River system supports a popular recreational and commercial fishery with runs of sockeye, chinook, coho, pink and chum salmon and steelhead. In 1960 the Robertson Creek spawning channel was opened at the headwaters of the Stamp River. It has now become a research - hatchery style facility directed towards the enhancement of chinook, coho and steelhead.

Sample sites include Stamp Falls Provincial Park, Stamp River at the Rod and Gun Club and Somass River at Vista Road (see Figure 4).

3.4 Little Qualicum River

The Little Qualicum River flows northeast and northwest for 11.6 km and enters the Strait of Georgia west of Qualicum Beach (see Figure 5). It has a drainage area of 248.6 km^2 and is fed by Cameron Lake. Whiskey and Kinkade Creeks are the Little Qualicum's

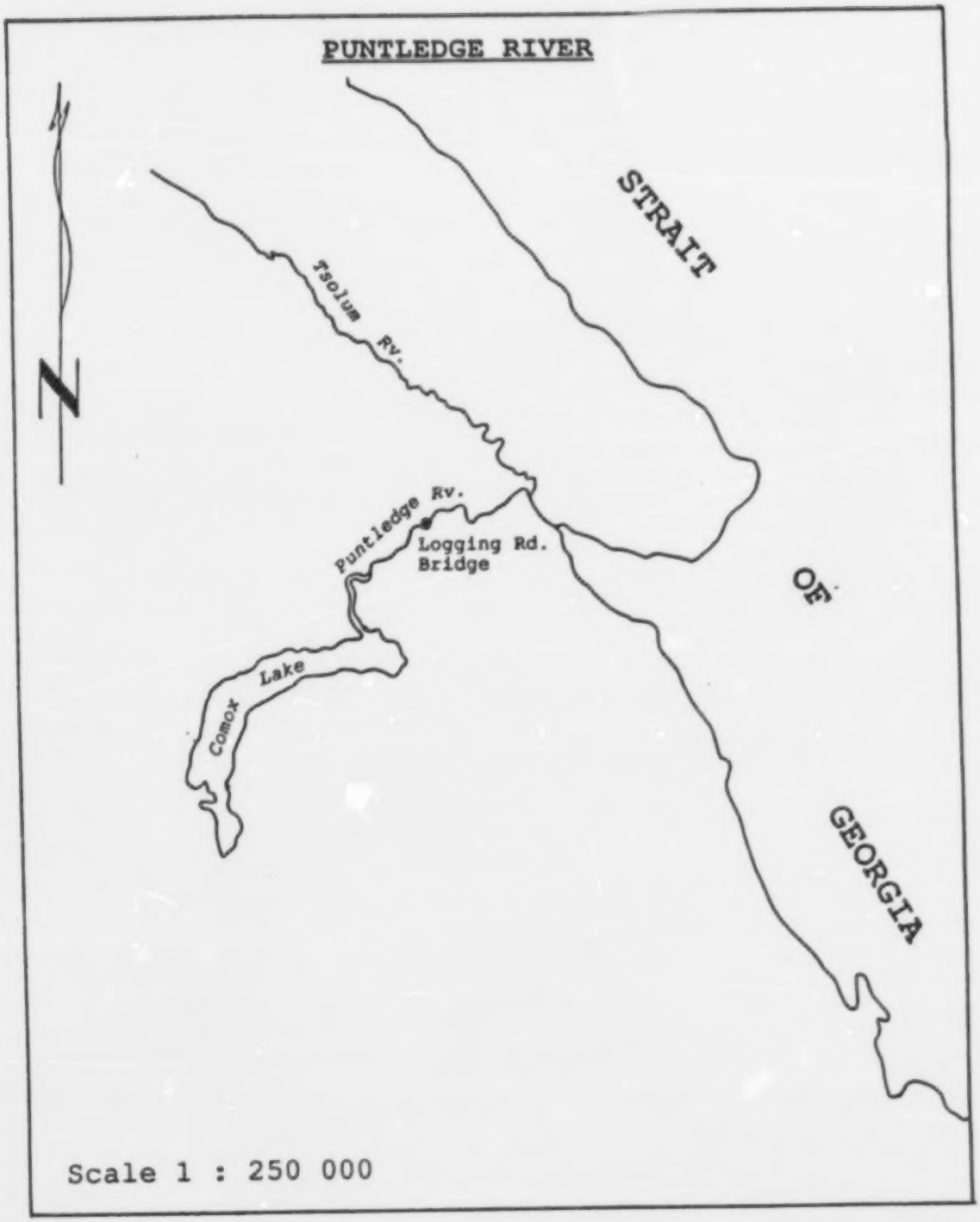

Figure 3: Map of the Puntledge River sample sites.

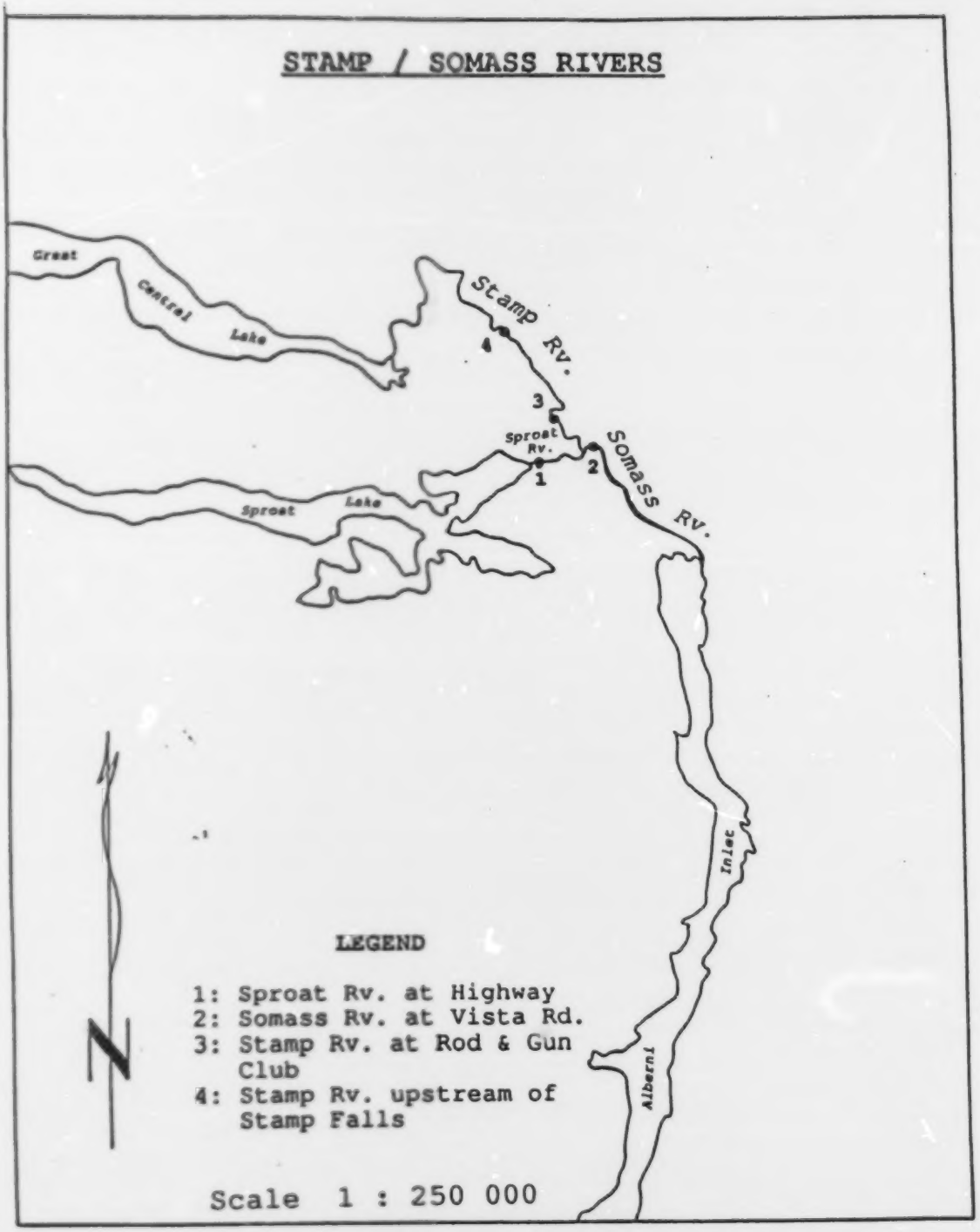

Figure 4: Map of the Stamp and Somass Rivers sample sites.

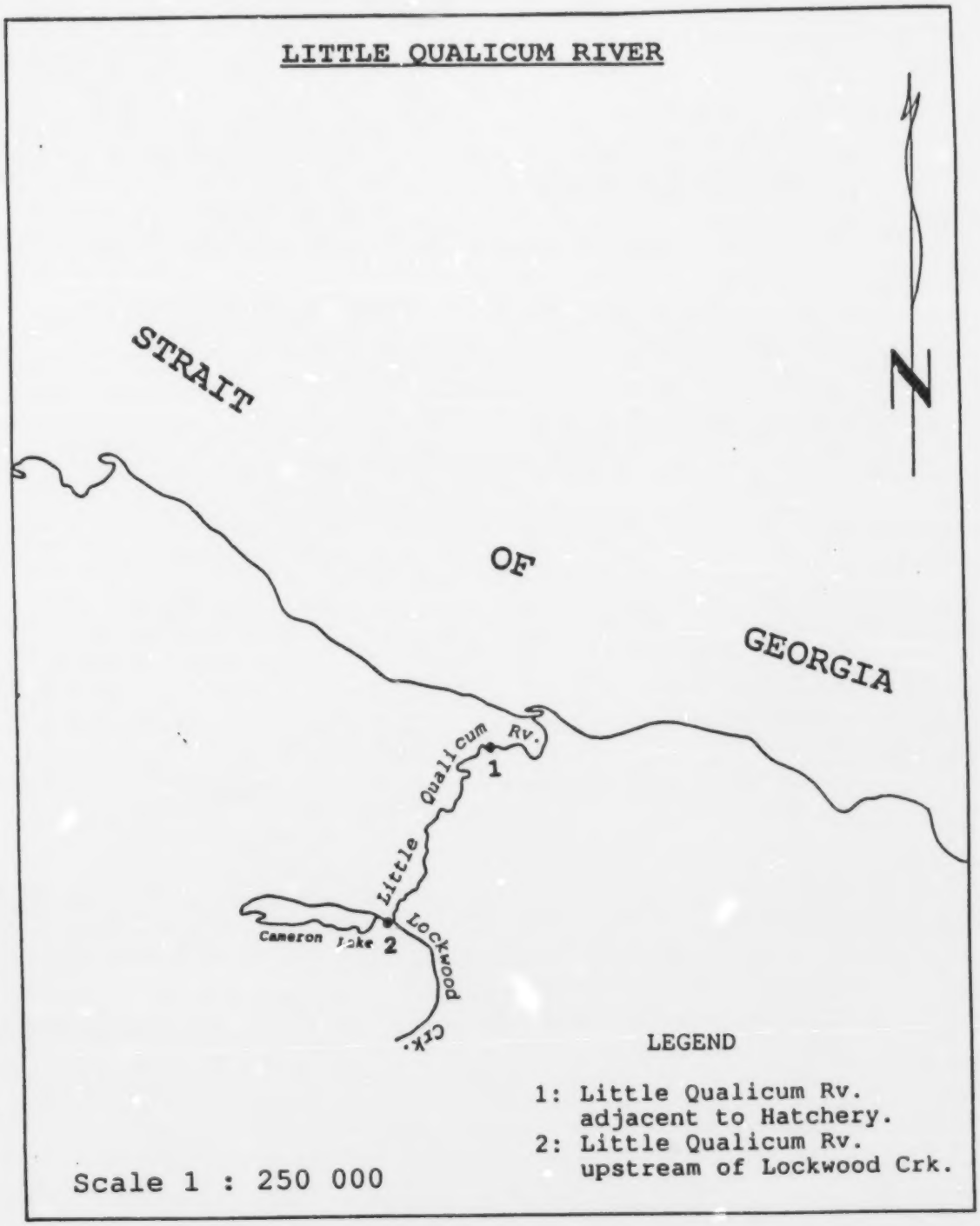

Figure 5: Map of the Little Qualicum River sample sites.

main tributaries.

The Little Qualicum provides a good recreational fishery with runs of chinook, coho and chum salmon, as well as rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*) and steelhead. Brown trout (*Salmo trutta*) are also found between Cameron Lake and Little Qualicum Falls. These falls are impassable to fish migrating upstream. The main natural spawning grounds for returning salmonids are located just below the falls; additional spawning channels have been constructed at the Little Qualicum Hatchery located approximately 4 km up the river. Other recreational activities include swimming and hiking, mainly through Little Qualicum Falls Park.

Sample sites were located upstream of Lockwood Creek and Little Qualicum River adjacent to the Hatchery (see Figure 5).

3.5 Oyster River

The Oyster originates in the mountains of Forbidden Plateau and has a drainage area of 376 km^2. It flows east for 20.9 km into the Strait of Georgia south of Campbell River (see Figure 6). This system experiences high flows in November due to fall rains and in May/June due to spring snowmelt. Minimum flows generally occur between August and October. The Oyster's main tributaries include Adrian Creek, Woodhus Creek, Piggott Creek and the Little Oyster River.

The Oyster River supports a significant sport fishery with populations of steelhead, sea-run and resident rainbow trout,

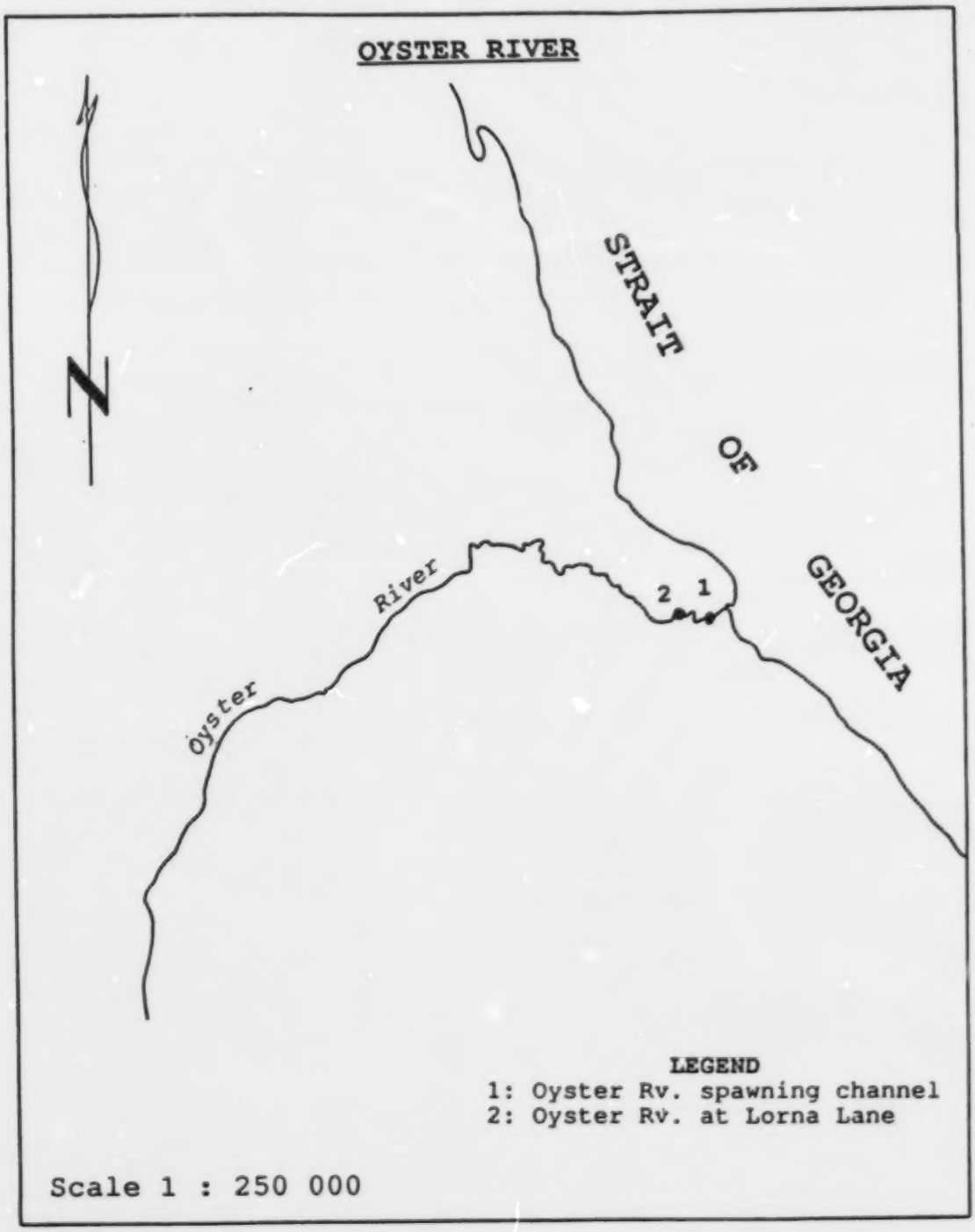

Figure 6: Map of the Oyster River sample sites.

chinook, coho, pink and chum salmon. A hatchery is located adjacent to the mainstem Oyster below the Little Oyster River confluence. There is also a sidechannel enhancement project located near the hatchery on UBC lands which accomodated the transplant of 2 000 000 pink eggs from the Quinsam River in 1986 (M.O.E., 1988) (see Figure 6). Other recreational activities include boating and swimming.

The sample sites on the Oyster River were located at the end of Lorna Lane (see Figure 6).

4.0 METHODS AND MATERIALS

4.1 Methods

This report includes only rivers which have had a history of *G. geminata* and those which were reported by fisheries staff and the public to be affected by an algal mat. Data collection was combined with other field work as often as possible. At each site dissolved oxygen (DO), pH, water temperature and flow was recorded. At sites where other work was being conducted nutrient levels (dissolved NO_3 + NO_2 and dissolved ortho-phosphates) were included in some water analyses. Some sites were also analyzed for chlorophyll a content to determine if they exceeded the Provincial Criteria of 10 $\mu g/cm^2$ for aquatic life or five $\mu g/cm^2$ for recreational use (Pommen, 1991). Overall growth patterns, as related to physical features such as flow and light exposure, were visually observed and recorded. Flow was estimated by timing floating sticks over a five metre length of stream.

Invertebrate diversity was visually observed as well as using a 0.09 m^2 Surber sampler. Invertebrate samples were preserved in a five percent ethanol solution. Taxonomic work and laboratory analyses were preformed by Zenon Environmental Laboratories in Burnaby, B.C. as outlined in Clark and Shera (1985).

4.1.1 Heber River rock transplant experiment

On April 9, 1991 three uncolonized rocks were transplanted from the upper Heber River to an area downstream where *G. geminata* has been found in the past. Similarly, On June 17, 1991 three

rocks covered with *G. geminata* (see Appendix II, No. 5) were moved from the lower Heber (E207793) to an area approximately 16 km upstream (see Figure 2). The purpose of this was to determine whether or not *G. geminata* would colonize in the pristine areas of the upper Heber and spread downstream and if rocks from the same pristine area would also be subject to colonization in downstream reaches. The rocks moved upstream were placed in an area free of *G. geminata* with moderate flow and sufficient depth to avoid summer dry periods. The rocks were checked on July 17, 1991.

4.1.2 Stamp River snorkel survey

Participation in a snorkel survey conducted by fisheries staff was included in order to document the distribution of *G. geminata* throughout the Stamp River. The swim was conducted on July 4, 1991 from the Rod and Gun Club to Vista Rd. (see Figure 4).

4.1.3 Little Qualicum channel scour

Spawning channels at the Little Qualicum Hatchery were scoured during the weeek of June 17, 1991. The substrate of the channel was previously covered with a mat of *G. geminata* approximately one centimeter thick. Upstream reaches of the spawning channel were intensely scoured while the downstream reaches were only lightly scarified. Observations at the facility were made on July 11 and 24, 1991 to determine any subsequent growth rates of *G. geminata* in the channel.

4.2 Materials

Materials and equipment used in this report included:

- DO meter: DO and water temperature readings
- pH meter: pH readings
- 250 mL and 500 mL polyethylene bottles: algae and invertebrate sample collection
- 0.09 m^2 Surber sampler: invertebrate collection
- Pentax 35 mm SLR and Nikonis 35 mm cameras
- Zeiss photomicroscope: photographs of the *G. geminata* vegetative cell.

5.0 RESULTS

5.1 Gold and Heber Rivers

On June 6, 1991 four sites were sampled on the Gold and Heber Rivers (see Figure 2). At site 0122380 the substrate was covered with detritus and silt and no sign of *G. geminata* was found. The flow at this site was less than the other sites. At site 0122385 *G. geminata* was found growing in tufts, approximately one cm^2, on cobble and small boulders. The growth appeared to be limited to areas along the bank where depth and flow were less than that of the midchannel area. Further upstream, at site E207792, no *G. geminata* was found although flow, temperature and nutrient levels (see Table 1) were similar to site 0122385. In the Heber River at site E207793 some *G. geminata* was found on the larger cobble in the slower waters long the left hand bank.

At each site samples were taken for nutrient analysis and invertebrate taxonomy and densities. The results are listed in Tables 1 and 2.

Table 1: Results of June 6, 1991 nutrient analysis for the Gold and Heber Rivers

Site No.	Diss. N Ammonia (mg/L)	Diss. NO3 + NO2 (mg/L)	Diss. O-Phos. (mg/L)
0122380	< 0.005	< 0.02	< 0.001
0122385	< 0.005	< 0.02	< 0.001
E207793	0.008	< 0.02	< 0.001
E207793	< 0.005	< 0.02	< 0.001

Table 2: Results of June 6, 1991 Surber samples for the Gold and Heber Rivers. Numbers represent specimens per 0.09 m^2.

Site No.	Chironomid	Mayfly	Stonefly	Caddisfly
0122385	7	5	0	4
E207792	2	8	1	2
E207793	1	0	0	0

On July 17, 1991 these sites were again sampled. Site 0122380 remained the same with no signs of *G. geminata*. At site 0122385 (see Appendix II, No. 9) the tufts had expanded to form complete coverage on the rocks but the growth was still limited to waters away from midstream. Some rocks were inspected visually for invertebrates and stonefly (Order Plecoptera), caddis fly (Order Tricoptera), mayfly (Order Ephemeroptera) and chironmid (Family Chironomidae) larvae were found. At site E207792 *G. geminata* was found growing in isolated areas, but the coverage and the thickness of the growth appeared to be much less than that at site 0122385. The algal mat in the Heber River, at site E207793 (see Appendix II, No. 10), had grown significantly since June 6 and at this time covered approximately 10% of the wetted width. Few invertebretes were found on rocks at this site however there was an abundance of chironomid larvae within the algal mat. This was also noted at all other sites.

5.1.1 Heber River rock transplant experiment

Gomphonema geminata had begun to colonize rocks transplanted

from the upper Heber by July 17, 1991. Colonized rocks transplanted from site E207793 to the upper Heber showed little change since June 17, 1991 (see Appendix II, No. 7) and no *G. geminata* was found within 100 m downstream of the transplant site (see Appendix II, No. 8). The water temperature at site E207793 was 11°C and was 9°C at the upper Heber site.

5.2 Puntledge River

On March 14, 1991 fisheries staff reported seeing tufts of diatoms growing on rocks in the Puntledge. By June 3, 1991 approximately 70% of the wetted width of the stream at the logging road bridge (see Appendix III, No. 1, 2) was covered with *G. geminata*. The algal growth was not found in the shaded areas along the right hand bank. The growth was heavy throughout the stream, including areas of shallow, fast flowing water over bedrock. On June 12, 1991 the site was again sampled and the mat appeared to be spreading in both area and thickness.

Coho fry were seen near rocks covered with *G. geminata*, but most were upstream of the algae with no *G. geminata* visible in the deeper reach immediately upstream. Caddis larvae were also seen on the mat, apparently feeding.

On July 8, 1991 it was reported that the downstream limits of the growth of *G. geminata* was the confluence of the Puntledge and Tsolum Rivers (see Figure 3) but was not in the Tsolum itself.

On July 9 this site was again checked and the mat had increased slightly in area but no increase in stalk length was

noted. By July 24, 1991 the *G. geminata* mat in the Puntledge had been greatly reduced in areas where the depth had been reduced but was still quite thick in areas where the water was deeper (0.1 - 1.0 m). The majority of invertebrates found were chironomids within the algal mat.

5.3 Somass River

On May 16, 1991 the Stamp River was sampled at the Rod & Gun Club and above Stamp Falls (see Figure 4) and no *G. geminata* was found. At the Rod & Gun Club caddis larvae, stonefly larvae and snails appeared to be abundant. On June 13, 1991 the Sproat River was sampled at the highway bridge (see Figure 4) and no *G. geminata* was found. In the Somass River at Service Road (see Figure 4) small tufts (0.5 cm^2) of *G. geminata* were found on cobble substrate. The growth was restricted to the shallower areas of the stream near the banks.

A snorkel survey was conducted on July 4, 1991 on the Stamp River from the Rod & Gun Club to Vista Road and on the Sproat River from Sproat Lake to its confluence with the Stamp. *Gomphonema geminata* was seen throughout this portion of the Stamp and was approximately two centimeters long in most areas. The growth appeared to be most extensive in areas at the beginning of the swim although the thickest and largest mats (0.5 m^2) were seen on large, midchannel boulders near Vista Rd. *Gomphonema geminata* did not appear to grow in areas deeper than two meters, with extremely fast or extremely slow currents or in shaded streamside areas. In areas

with faster currents *G. geminata* did not appear to grow on the top surface of cobble, but instead on the sides of the cobble where flow was decreased. Throughout the swim pieces of the diatom mat were seen floating downstream. There was no *G. geminata* found in the Sproat River until just upstream of its confluence with the Stamp.

Salmon parr (chinook and coho) appeared to avoid areas with an extensive covering of *G. geminata*, while in the deeper, faster, algae free reaches of the Stamp there were high concentrations of parr.

On July 11, 1991 there was a thin, patchy covering of *G. geminata* in reaches immediately above Stamp Falls. The algae could not be seen in the midchannel areas of the stream. Caddis larvae were seen in low numbers on substrate while chironmids were abundant within the algal mat. The distribution of *G. geminata* growth at the Rod & Gun Club was similar to that above Stamp Falls but the mat itself was much thicker. Again the majority of invertebrates found were chironomids within the algal mat. At Vista Rd. there was less *G. geminata* than at the upstream sites. Any tufts found were smaller in area but had longer stalks. In addition to an abundance of chironomids in the algal mat there was a high concentration of mayfly larvae. No *G. geminata* was found in the Sproat River. The temperature in the Sproat (20°C) was higher than that of the Stamp (17°C - 18°C) and invertebrate densities appeared to be considerably higher. Caddis were present in substantial numbers in addition to stonefly and chironomids.

5.4 Little Qualicum River

A site above Lockwood Creek (see Figure 5) was sampled on May 16, June 13 and July 11, 1991. *Gomphonema geminata* was not found during any of these samplings. Mayfly and stonefly larvae were abundant in the riffles.

On June 6, 1991 it was reported that *G. geminata* had established itself in the spawning channel at the Little Qualicum Hatchery. On June 13, 1991 the Little Qualicum River adjacent to the hatchery (see Figure 5) was sampled and a thin diatom mat (0.25 cm) was found covering much of the substrate. Areas of the stream which were heavily shaded were not affected. Salmonid fry were abundant in this area and in certain portions there were high concentrations of caddis larvae. The water temperature was 14°C at this time. On July 11, 1991 the mat had grown to a thickness of one centimeter and was covering 95% of the wetted width. The water temperature was 17°C. Chironomid larvae were abundant within the mat and mayfly were also present. Caddisfly larvae were found on the substrate. This site was again sampled on July 24, 1991. At this time the depth had dropped considerably and the *G. geminata* mat had reached a thickness of approximately two centimeters. The water temperature was 18°C and the current was comparable to previous dates. Chironomid larvae were present in the algal sample taken but not in as high a density as previously found. No caddisfly larvae were found.

5.4.1 Little Qualicum channel scour

On July 11 and 24, 1991 the upper reaches of the spawning channel was checked for post scouring growth of *G. geminata*. None was found. In the lower reaches of the spawning channel the substrate was not scoured as extensively as the upper reaches and some growth was still present on the substrate.

5.5 Oyster River

Gomphonema geminata was not found in the Oyster River until July 17, 1991 at Lorna Lane (see Figure 6). At this time only a few small (0.5 cm^2) tufts were found (see Appendix VI, No. 3) and were not overly abundant throughout the reach. This site was again sampled on July 24 and a higher number of the small tufts were found, both throughout the reach and on individual rocks. The growth of *G. geminata* was heavier in areas along the right hand side of the stream (see Appendix VI, No. 4). It appeared to grow better in areas with a substantial current but not in areas where the current was at either a maximum or minimum. Chironomid larvae were found in extremely high numbers within the algal sample taken. Caddisfly larvae were also noted on the substrate.

6.0 DISCUSSION

6.1 Distribution

During the study period, *G. geminata* was found in the Gold, Heber, Oyster and Stamp/Somass Rivers as in previous years. It was also found in the Puntledge and Little Qualicum Rivers where it had not previously been known to exist.

It is interesting to note that the extent of *G. geminata* appears to be limited to mid Vancouver Island streams on both the east and west coasts. It has not been found in any northern or southern Island streams, even though many are physically similar to those already affected. Based on observations in the field, rivers such as the Cowichan or the Nanaimo would provide ideal habitat for the colonization of *G. geminata* yet none has been found. It has also not been found in any mainland coastal streams.

It was difficult to determine the complete distribution of *G. geminata* throughout a given stream because of time limitations but some general observations were made. It was not found in the lower reaches of a stream which were under tidal influences or reaches near lake outlets such as portions of the Little Qualicum directly below Cameron Lake. *Gomphonema geminata* appears to be stream specific; in many cases it was found to inhabit a stream but not the stream's tributaries. This observation suggests a possible common denominator in the five affected streams. Physical and/or chemical conditions in the tributaries may not be ideal for the growth of *G. geminata*. This was illustrated at the confluence of the Puntledge and Tsolum Rivers which marked the downstream limit

of *G. geminata* in the Puntledge. The Tsolum has high concentrations of copper due to acid mine drainage (Erickson & Deniseger, 1987) and this may alter the chemical makeup of the Puntledge enough to prevent the growth of *G. geminata*. The Heber River has had heavier growths of *G. geminata* than the Gold, both historically and in 1991. This may suggest that either physical or chemical conditions were not as favourable in the Gold as they were in the Heber.

6.2 Possible Growth Factors

6.2.1 Depth and flow

The hydrological characteristics of a stream may be as influential to the growth of periphyton as any other factor. Work by Biggs and Close (1989) suggests that hydrological regime may be as important as nutrients and that periphyton can only respond to available nutrients during low and stable flow regimes. Under artificial conditions current velocity was found to be a major factor in influencing the growth rates and community structures of diatoms (Korte & Blinn, 1983). Antoine and Benson-Evans (1986) found that the spatial and temporal distribution of *G. geminata* in the River Wye, Wales indicated its growth and expansion favoured periods of low flow.

The establishment of *G. geminata* in the Gold and Heber Rivers may be related to a succession of below average winter flows (<4 m^3/s) from 1985 to 1989. Winter flows had been greater than 4 m^3/s for 26 of the previous 27 years and the reduced flows may have

led to an increase in organic buildup within the substrate. This may have been an additional source of nutrient input. Also, a lack of scouring may have resulted in the establishment of an algal community earlier than normal and therefore increased growth.

Gomphonema geminata appears to have some flow and depth requirements in order to grow. It was not found growing in water deeper than 1.5 - 2.0 m. A possible upper depth limit was also observed. In the Puntledge *G. geminata* was found growing in water less than 10 cm deep (see Appendix III, No. 5). As the summer progressed and water levels decreased the thickness of the algal mat also decreased. It may be that the growth of *G. geminata* is inhibited by ultraviolet rays which are normally filtered by the deeper water.

Gomphonema geminata was rarely observed in portions of a stream exposed to maximum or minimum flow. Only in reaches with bedrock substrate, such as sections of the Puntledge (see Appendix III), was it found growing in the faster currents. In a stream composed of a bedrock substrate periphyton would be less vulnerable to bedload movement, which causes severe physical abrasion (Biggs & Close, 1989). In reaches of minimum flow it is likely that available nutrients and the movement of repoductive cells are limited and therefore so is the growth of *G. geminata*.

6.2.2 Substrate

The nature of substrate surfaces may influence diatom colonization rates and community structures (Korte & Blinn, 1983).

Diatom colonization may be more rapid on substrate which is covered with a well developed primary film consisting of organic material, bacteria and fungal hyphae, especially in riffle areas (Gorden et al, 1969; Paerl, 1980; Blinn, Fredericksen & Korte, 1980; Korte & Blinn, 1983). A number of studies (Fritsch, 1929; Gessner, 1955; Gumtow, 1955; Round, 1981; Munteanu and Maly, 1981) have suggested that algal densities are higher on the upstream face of substrate because dessiminules transported by the stream are more likely to come into contact with this surface. The downstream surface of substrate is exposed to a reversed current caused by a microeddy which is created by the substrate position in the streambed (Munteanu & Maly, 1981). This would allow dessiminules to settle on the downstream surface. Jaag and Ambuhl (1964) demonstrated a thin boundary layer on the top surface of the substrate where the velocity is reduced, however because of exposure this surface is more likely to be invaded by already established colonies (Munteanu & Maly, 1981).

The growth patterns observed in this study suggest that *G. geminata* is influenced by substrate. Cobble and small boulder substrates were initially colonized on the upstream or downstream surfaces with the top surface being the last covered. Areas of the Puntledge with bedrock substrate had extensive coverage of *G. geminata* earlier than other streams. Bedrock is not subject to movement and as a result the primary film covering the surface may be left intact promoting the growth of periphytic diatoms.

6.2.3 Water temperature

High water temperatures are favourable to the growth and expansion of *G. geminata* (Antoine & Benson-Evans, 1986). Bothwell, Jasper and Daley (1989) concluded that maximum growth rates of algae are affected seasonally by temperature, which in turn is affected seasonally by daylight. Other studies (Brown & Krygier, 1970; Hansman & Phinney, 1973) have shown significant increases in water temperature in streams affected by clearcut logging. Hansman and Phinney (1973) also concluded that the primary production of a stream was much higher after being affected by clearcut logging.

Each stream observed in this study displayed an increase in growth and coverage of *G. geminata* as water temperature increased. Although the temperatures of these streams vary seasonally they may be further affected by logging practices within each stream's watershed. Loss of riparian vegetation would reduce shade coverage and in turn increase water temperature. Possible variations in growth due to temperature were observed in the Heber River. *Gomphonema geminata* appeared to be growing well in the lower portions of the Heber where the water temperature was 11°C in mid July. Rocks colonized with *G. geminata* which were transplanted to upstream reaches of the Heber, where the water temperature was only 9°C did not experience an increase in coverage (see Appendix II, No. 7). This may have been, in part, due to the lower temperature of this reach.

6.2.4 Aspect

The intensity of available light may affect the growth of some diatom taxa. In work by Robinson and Rushforth (1987) species of *Gomphonema* were not found in reaches which were covered with a closed canopy. The direction of a stream's flow will affect the amount of available light. Reaches lying in an east/west axis will be exposed to available light for longer periods than reaches lying in a north/south axis. This would be favourable to the growth and expansion of *G. geminata* (Antoine & Benson-Evans, 1986).

North/south oriented reaches generally had limited coverage of *G. geminata* along the stream banks which may have been caused by reduced exposure to sunlight because of riparian vegetation. This was evident in the Stamp River during a July 4 snorkel survey. East/west oriented reaches, such as the Little Qualicum at the hatchery, exhibited a heavy growth of *G. geminata* throughout the entire wetted width despite heavy riparian growth (see Appendix V, No. 1).

6.2.5 Nutrients

Algae can exhibit a wide range of growth rates under steady state, phophorus (P) limited conditions with very small fluctuations in ortho-phosphate (OP) concentrations (Deniseger & Erickson, 1990). Studies (Bothwell, 1985; Bothwell, Jasper & Daley, 1989) have suggested that periphyton growth rates are saturated at very low levels (<1.0 ppb) of soluble reactive phosphorus. This may help explain the extensive growth of *G.*

geminata in rivers which consistently exhibit low concentrations of nutrients. OP levels in the Heber River at E207793 averaged 0.0015 mg/L between July 6, 1989 and September 20, 1990 with a maximum value of 0.002 mg/L. Similarily in the Oyster at 0125580 OP levels were consistently less than 0.003 mg/L from June 17, 1987 to November 13, 1989. If *G. geminata* does respond favourably to increases in OP, the increases appear so insignificant that the source would be difficult to determine.

It has been shown that positive periphytic responses to nutrient levels are dependent on low and stable flow regimes (Antoine & Benson-Evans, 1986; Biggs & Close, 1989). It has also been demonstrated that algal growth may be dependent on the type of nutrients being added. Pringle and Bowers (1984) found that additions of NO_3 only, had no effect on algal growth; additions of PO_4 only, which would lower the nitrogen phosphorus ratio (N:P), resulted in biovolumes two times greater than control areas and additions of PO_4 + NO_3 (N:P = 25:1) resulted in biovolume increases four times greater than control areas. Because P increases have been undetectable in affected streams P additions may have to accumulate before reaching the level at which the subsequent growth of *G. geminata* becomes significant. It is likely that small amounts of OP would be taken up quickly by the periphyton making the detection of P increases more difficult. The lack of growth of *G. geminata* on rocks transplanted to the upper Heber is also likely influenced by the lack of drifting dessiminules from upstream reaches.

6.2.6 Winter scour

Flooding, which is typical of Vancouver Island streams during autumn months, causes periphyton removal two distinct processes (Biggs & Close, 1989). Water velocities increase near streambeds which results in an increase of shear stress on the algal community. Secondly, floods initiate bedload movement which causes severe physical abrasion. Biggs and Close (1989) also discuss a third possibility: the abrasive effects of suspended solids. The degree of flooding may also be related to the watershed itself. Streams which are not lake fed would flood more violently as lakes tend to buffer flows during periods of high rainfall.

Many Vancouver Island streams experienced severe flooding during the fall of 1991. In a system such as the Oyster, with a substrate consisting largely of cobble and boulder, the effects of winter scour would be more complete than a stream with a bedrock substrate. In addition to the removal of periphytic communities, the primary film described in Section 6.2.2 may also be removed as a result of bedrock movement. This may help explain the late appearance of *G. geminata* in the Oyster while it thrived in the Puntledge, which has a bedrock substrate and is lake fed. *Gomphonema geminata* expanded quickly in the Little Qualicum, which is fed by Cameron Lake, and in the spawning channel located adjacent to the Little Qualicum, which has a controlled flow. The Heber River also showed evidence which may be related to extensive winter scouring. Periphyton samples taken on July 31, 1990 resulted in a count of 2,862,536.0 *G. geminata* cells per cm^2, while

counts from July 17, 1991 showed only 32,348.5 cells/cm^2. Although this data is preliminary it may suggest that the growth of *G. geminata* was not as extensive in the Heber in mid July, 1991 as it was in late July, 1990.

6.2.7 Invertebrates

Rapid increases in algal biomass are a natural response to changing environmental conditions and healthy invertebrate populations help control these increases. A lack of herbivores, however, will allow increases in algal biomass to go unchecked (Deniseger & Erickson, 1990)

Some studies (Lambert *et al*, 1987; DeNicola *et al*, 1990) have shown the caddisfly (*Dicomoecus sp.*) to be the most effective macroinvertebrate at altering algal biomass and community succesion. Using mouthparts and tarsal claws caddisfly quickly clear areas of filamentous overstory and thick understory mats.

Caddisfly larvae were noted in the Little Qualicum and the Puntledge, but gradually disappeared as the growth of *G. geminata* increased. In streams, some macroinvertebrates avoid grazing algal filaments that are large or mucilaginous (Brown, 1961; Hambrook & Sheath, 1987; McShafferty & McCafferty, 1988; DiNicola *et al*, 1990) because the size of the filaments interferes with the movement of the palps. In mid June caddisfly larvae were seen on the *G. geminata* mat in the Puntledge and Little Qualicum, presumably feeding. It appears that as *G. geminata* increases in size it may become a less desirable food source. By late July caddisfly larvae

were not found in the affected reaches of the Puntledge or Little Qualicum, however, in the Little Qualicum high numbers of caddis larvae were seen on the substrate of the clean, downstream reaches. The larvae seen in these reaches may have migrated downstream to areas where algal communities were more suited to the caddis feeding apparatus.

In all affected streams there was a high occurence of chironomid larvae and, to a lesser degree, mayfly larvae within in the algal mat. This was different from previous years where invertebrates were present only in low numbers. These invertebrates were abundant in both the early stages of diatom colonization and large, established mats of *G. geminata*. This observation and the small size of these animals suggests that chironomid and mayfly larvae do not restrict the growth of *G. geminata* through grazing.

6.3 Impacts

6.3.1 Fisheries values

Low numbers of juvenile salmonids appeared to be associated with areas of extensive *G. geminata* coverage. This was evident during the Stamp River snorkel survey; salmonid parr were abundant in areas where *G. geminata* growth was limited but seemed to avoid areas containing heavy growth. In the Little Qualicum, fry occurence decreased as the growth of G. geminata increased. It is not clear whether this was caused by the presence of the algal mat or was a part of normal out migration. This may be due to

suspended frustules, which may have caused gill irritations, or a reduction in available food with invertebrates less abundant or hidden in the algal mat.

An established mat of *G. geminata* may cause a restriction of flow through substrate and reduced DO levels due to algal respiration and decay (Deniseger & Erickson, 1990). In the lower, clean reaches of the Little Qualicum an abundance of sculpins was noted within the cobble substrate. None were found in the colonized reaches and this may be due to lack of flow. If this reduced flow does exist fry survival rates may be affected in streams where *G. geminata* is established before fry emergence.

Gomphonema geminata has, in the past, blocked the intake screens at the Oyster River spawning channel during fall die off. It is possible that the same problem will be experienced at the Little Qualicum and Puntledge facilities.

6.3.2 Invertebrate communities and densities

Invertebrate communities and densities appeared to be altered in reaches affected by *G. geminata*. Caddisfly and stonefly numbers decreased while chironomid and mayfly numbers increased. In reaches not affected by *G. geminata* invertebrate communities appeared to be more diverse. A 0.18 m^2 section of substrate in the Nanaimo River produced 10 caddisfly larvae, two stonefly larvae and one chironomid larvae. Undersides of substrate in the Sproat River were examined in early July and showed high numbers of caddisfly, stonefly, mayfly and chironomid larvae. In reaches affected by *G.*

geminata no invertebrates were found on the underside of the substrate material. This may be a result of flow restriction in the interstitial spaces of the substrate.

Chironomid numbers and, in some cases, mayfly numbers were extremely high in *G. geminata* mats suggesting that these animals benefit from the growth of *G. geminata*. The thick, filamentous growth pattern of *G. geminata* provides excellent hiding cover and the polysaccharide stalk provides a possible food source.

6.3.3 Aesthetics

Samples were taken for chlorophyll a analysis from the Gold and Heber Rivers on July 17, 1991 to compare levels to the Provincial Criteria of 10 $\mu g/cm^2$. As of August 29, 1991 these results were not yet available. Data has shown levels to be as high as 115.4 µg/cm2 in the Heber River on Sept. 12, 1989 and 47.7 $\mu g/cm^2$ in the Gold River on Aug. 15, 1989.

Gomphonema geminata gave the affected streams an aesthetically displeasing appearance as the algal mat spread. In streams with popular swimming areas, such as the Puntledge and the Gold, it is possible that *G. geminata* had an adverse affect on the recreational value of the stream.

6.3.4 Water quality

Water quality analyses were conducted on the Gold, Heber and Oyster Rivers. The results indicated that the quality in these streams had not been changed with the presence of *G. geminata*.

This is consistent with observations from previous years. DO levels for the affected streams ranged from 9.0 ppm to 12.0 ppm but were not consistently measured because of equipment problems. The DO levels of the affected streams may decrease during the fall die off. These decreases may not be significant, however, because of the tendency for G. geminata to be washed out of a stream in large pieces. This would reduce the amount of biomass which would actually decay in the stream. Chlorophyll *a* levels were not available (see 6.3.3) and therefore could not be compared to the Provincial Criteria of five $\mu g/cm^2$ for aquatic life in streams.

7.0 CONCLUSIONS

Gomphonema geminata was found in six mid Vancouver Island streams during the summer od 1991: the Puntledge, Little Qualicum, Gold, Heber, Oyster and Stamp/Somass Rivers. The success of the alga appeared to be related to a number of variables. Upper and lower depth limits of <0.1 m and 1.5 - 2.0 m, respectively, were observed. Areas of maximum or minimum flow also appeared to restrict growth. The growth of *G. geminata* appeared to increase as water temperature and available light increased but could not be associated with any changes in nutrient concentrations because of low nutrient levels in the affected streams. The degree of winter scour also appeared to ~~to~~ effect the growth of *G. geminata*. After the high winter flows of 1990, *G. geminata* appeared to grow better in lakefed streams with a bedrock substrate (i.e. Puntledge River) than in mountain fed streams with a unstable substrate (i.e. Oyster River). The fact that *G. geminata* was not found in the tributaries of the affected streams suggests that, in addition to physical requirements, there is also a chemical requirement which could not be determined.

Gomphonema geminata mats appeared to provide favourable habitat for smaller invertebrates such as chironomid and mayfly larvae and unfavourable habitat for the larger caddisfly larvae. Interstitial dwelling invertebrates such as stonefly larvae also appeared to be adversely affected. Salmonid parr appeared to avoid areas of dense growth; this may have been caused by frustules held in suspension which may have caused gill irritations.

8.0 ACKNOWLEDGEMENTS

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APPENDIX I

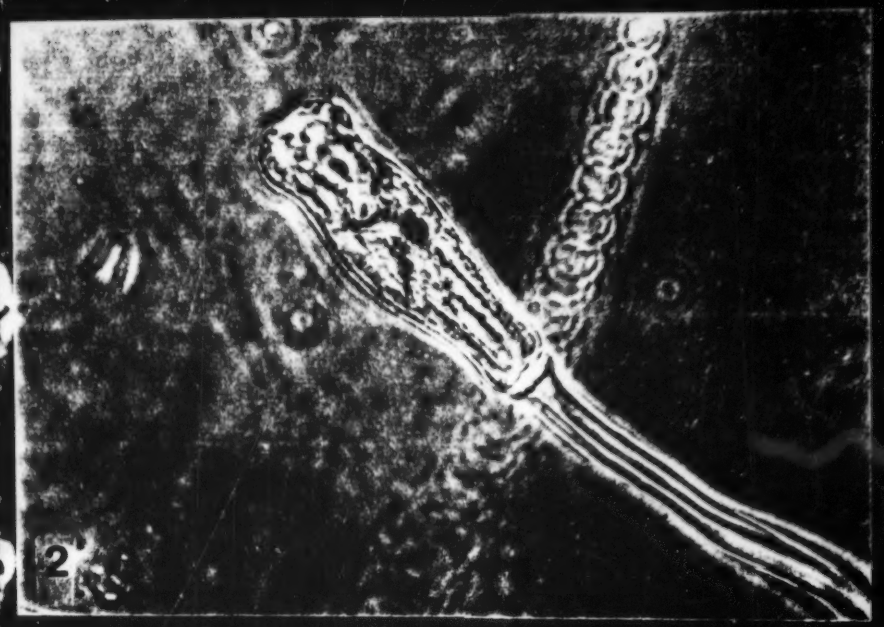
Microscopic Photographs of *Gomphonema geminata*

No. 1: Valve view (left and right) and girdle view (centre) of *G. geminata*.

No. 2: *G. geminata* stalk.

No. 3: Mass of stalks.

No. 4: Valve view of *G. geminata*.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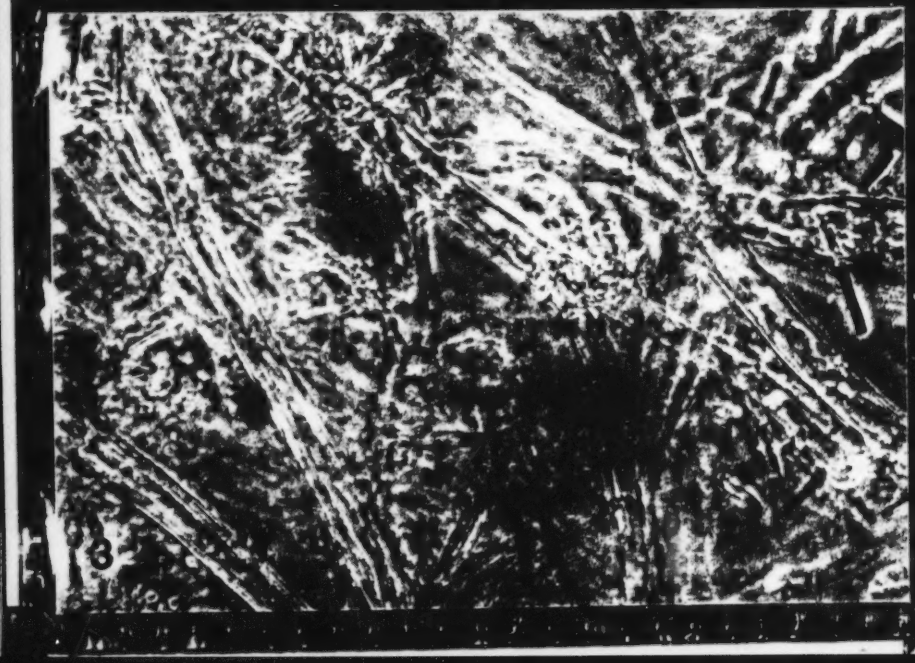
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APPENDIX II

Growth of *G. geminata* in the Gold and Heber Rivers

No. 1: Downstream view of the Heber Rv. at E207793.

No. 2: Upstream view of the Heber Rv. at E207793.

No. 3: Upstream view of the Gold Rv. at E207792.

No. 4: Gold Rv. at 0122385.

No. 5: Rocks colonized with G. geminata to be transplanted from the lower Heber to the upper Heber, June 17, 1991.

No. 6: Heber River rock transplant, June 17, 1991.

No. 7: Transplanted rocks on July 17, 1991 showing minimal growth.

No. 8: Clean reaches approximately 100 m downstream of transplanted rocks.

No. 9: Gold River at Big Bend, site 0122385.

No. 10: Gold River at highway, site E207792.

No. 11: Heber River algal mat, Sept., 1990.

No. 12: Heber River algal mat, Sept., 1990.

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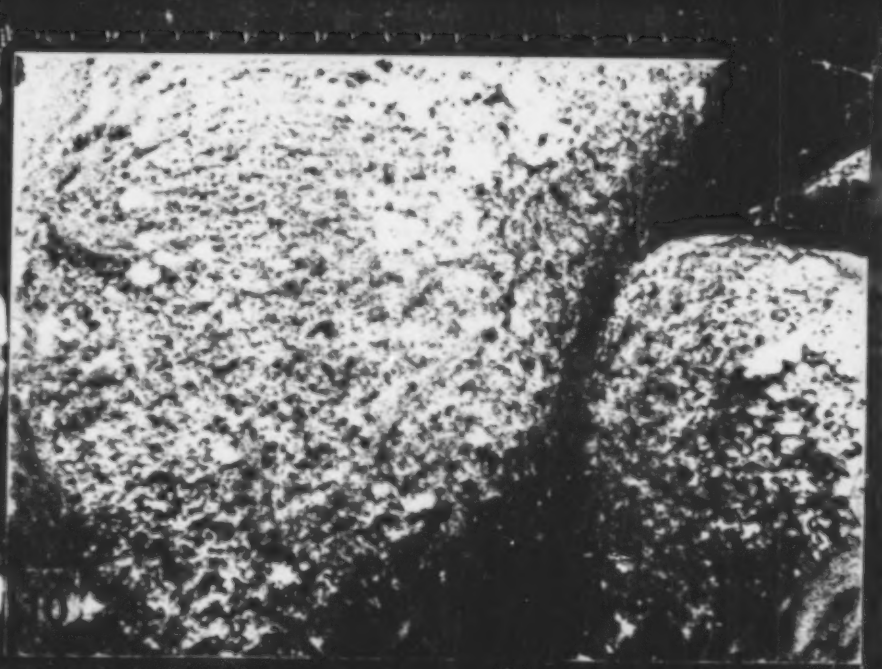

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APPENDIX III

Growth of *G. geminata* in the Puntledge River

No. 1: Puntledge River upstream of logging road bridge. Brown areas of substrate are areas colonized with *G. geminata*.

No. 2: Puntledge River downstream of logging road bridge showing areas colonized by *G. geminata*.

No. 3: Substrate covered with *G. geminata* in approximately 1.0 m of water.

No. 4: Deteriorating *G. geminata* mat in approximately 0.2 m of water.

No. 5: Extensive deterioration of *G. geminata* mat. Substrate at the top of the photo is less than 0.1 m deep.

APPENDIX IV

Growth of *G. geminata* in the Stamp and Somass Rivers

No. 1: Stamp River at Rod & Gun Club.

No. 2: Stamp River upstream of Stamp Falls.

No. 3: Stamp River upstream of Stamp Falls before the appearance of *G. geminata*, May 15, 1991.

No. 4: Stamp River at Rod & Gun Club. Substrate is covered with detritus but no *G. geminata* is present, May 15, 1991.

No. 5: Stamp River upstream of Rod & Gun Club. *G. geminata* mat is beginning to form. Note that there is no growth on top of the individual rocks.

No. 6: Stamp River substrate in faster current showing limited growth of *G. geminata*.

No. 7: Stamp River substrate in minimum flow showing no growth of *G. geminata*.

No. 8: *G. geminata* beginning to colonize large boulders in the Stamp River, July 4, 1991.

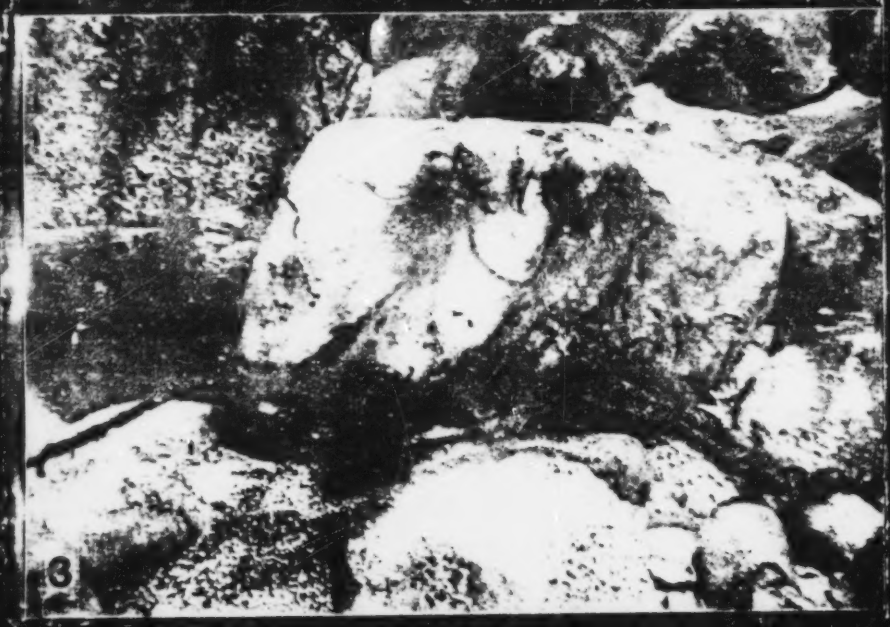
No. 9: Stamp River upstream of Stamp Falls, July 11, 1991.

No. 10: Stamp River at Rod & Gun Club, July 11, 1991.

No. 11: Stamp River *G. geminata* mat.

No. 12: Somass River at Vista Rd., July 11, 1991.

No. 13: Sproat River with no *G. geminata* growth, July 11, 1991.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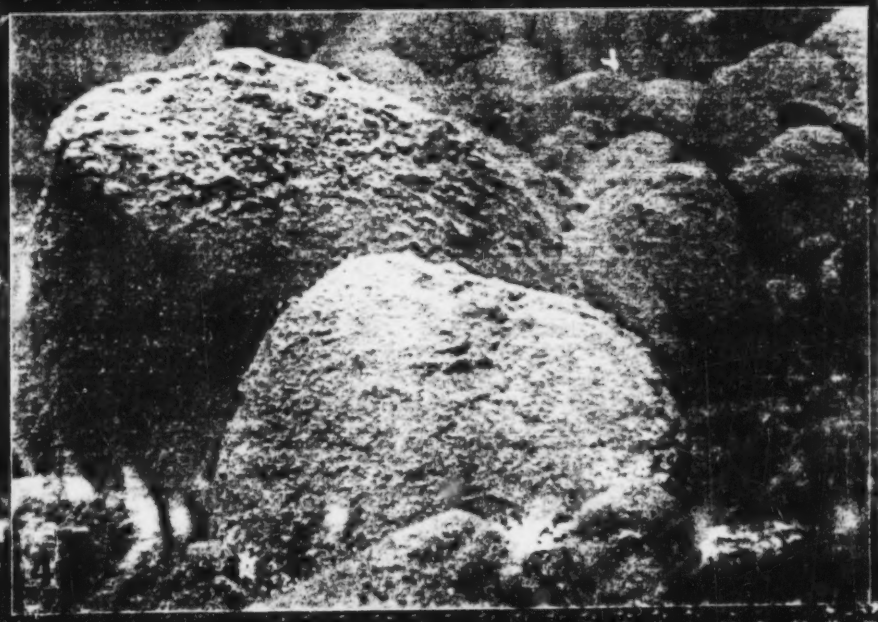

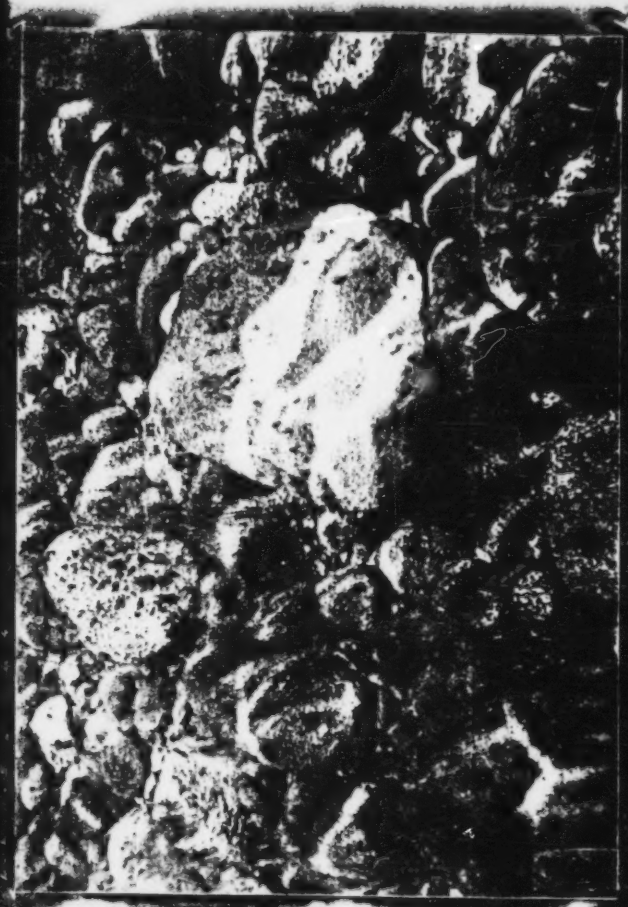

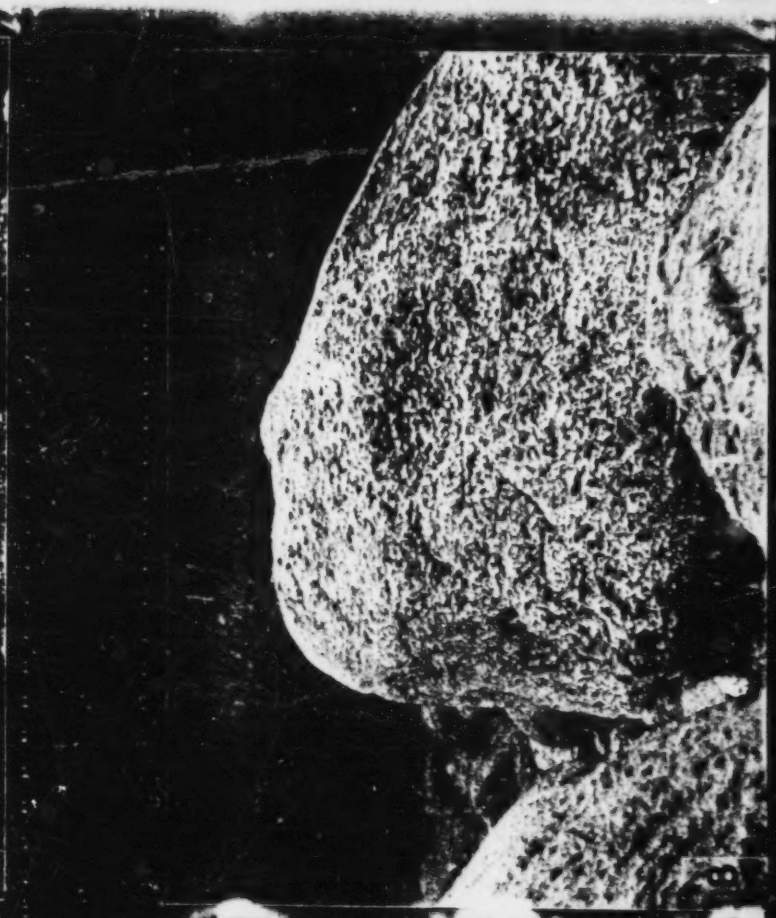

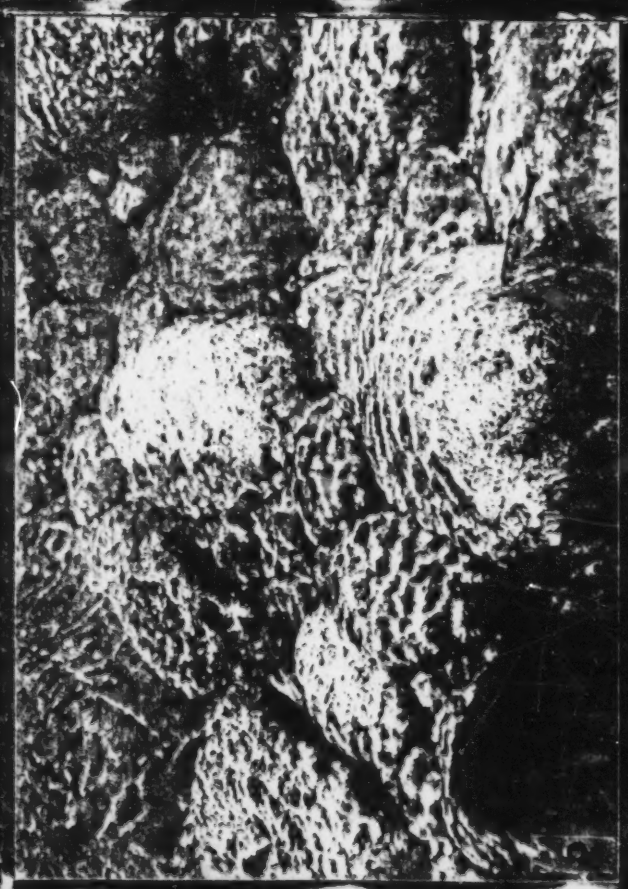

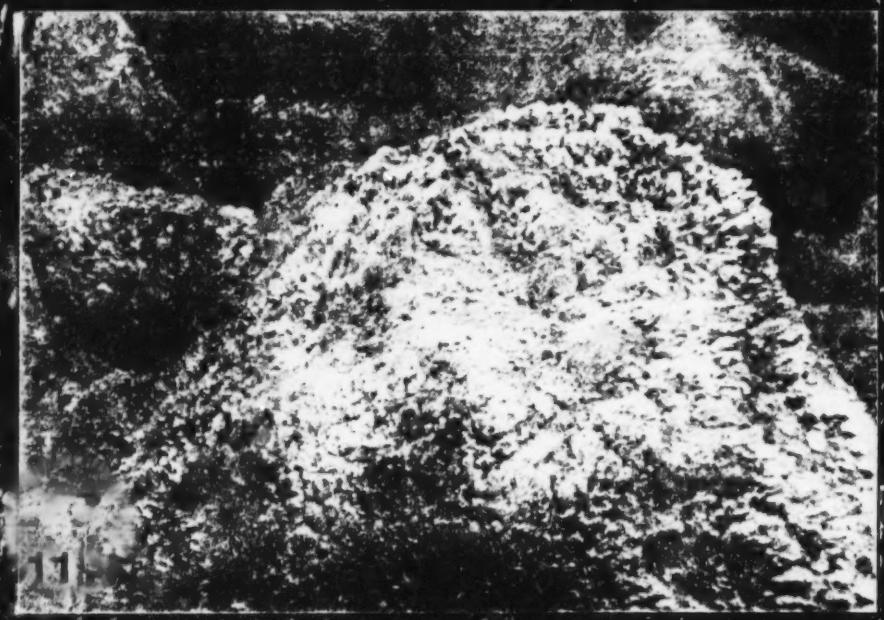

APPENDIX V

Growth of *G. geminata* in the Little Qualicum River

No. 1: Little Qualicum River adjacent to the hatchery.

NO. 2: Little Qualicum spawning channel.

No. 3: *G. geminata* mat in the Little Qualicum, July 24, 1991.

No. 4: Spawning channel substrate after scouring, July 24, 1991.

No. 5: Little Qualicum River upstream of Lockwood Creek with no *G. geminata*.

No. 6: Clean substrate in the Little Qualicum downstream of the hatchery.

No. 7: Caddisfly larvae on Little Qualicum substrate downstream of the hatchery.

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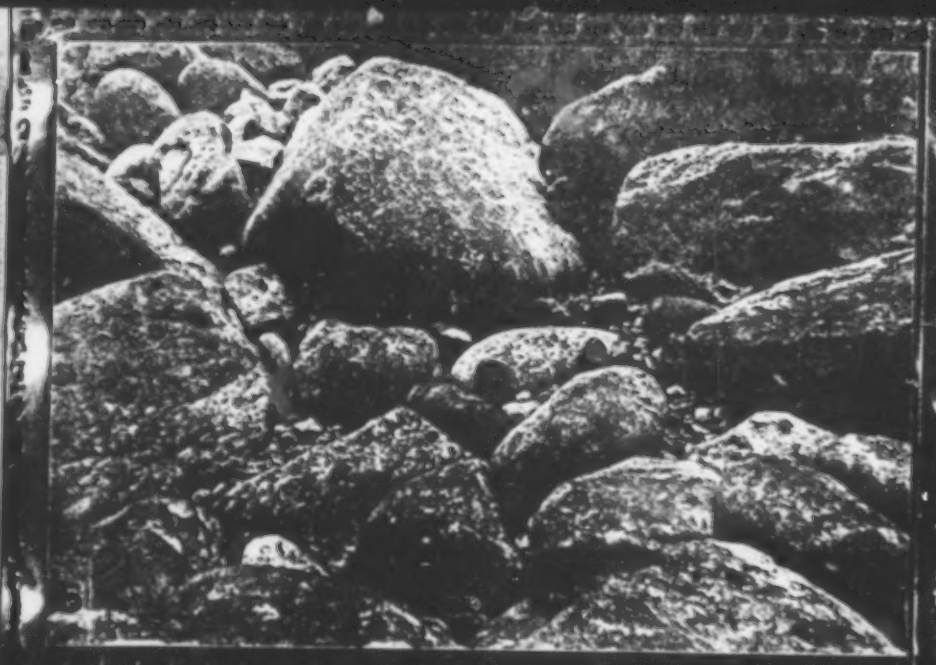

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APPENDIX VI

Growth of *G. geminata* in the Oyster River

No. 1: Upstream view of the Oyster Rv. at Lorna Lane.

No. 2: Downstream view of the Oyster Rv. at Lorna Lane.

No. 3: Early stages of *G. geminata* colonization along the left han bank of the Oyster River at Lorna Lane, July 24, 1991.

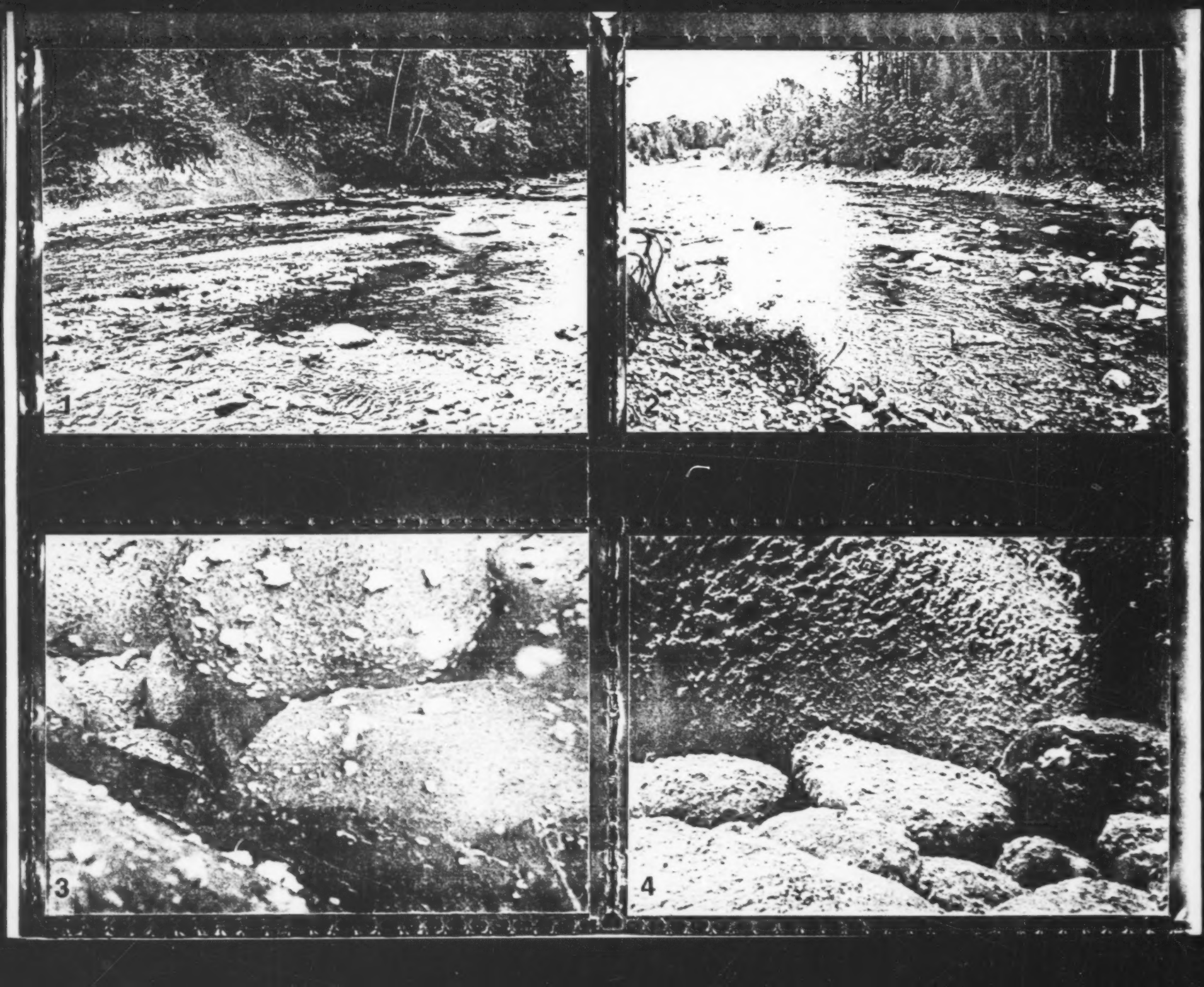
No. 4: *G. geminata* mat along the right hand bank of the Oyster River at Lorna Lane, July 24, 1991.

No. 5: Oyster River at Lorna Lane, July 30, 1991.

No. 6: Oyster River at Lorna Lane, July 30, 1991.

No. 7: Oyster River at Lorna Lane, July 30, 1991.

No. 8: *G. geminata* growing on solid substrate in fast current, Oyster River at Lorna Lane, July 30, 1991.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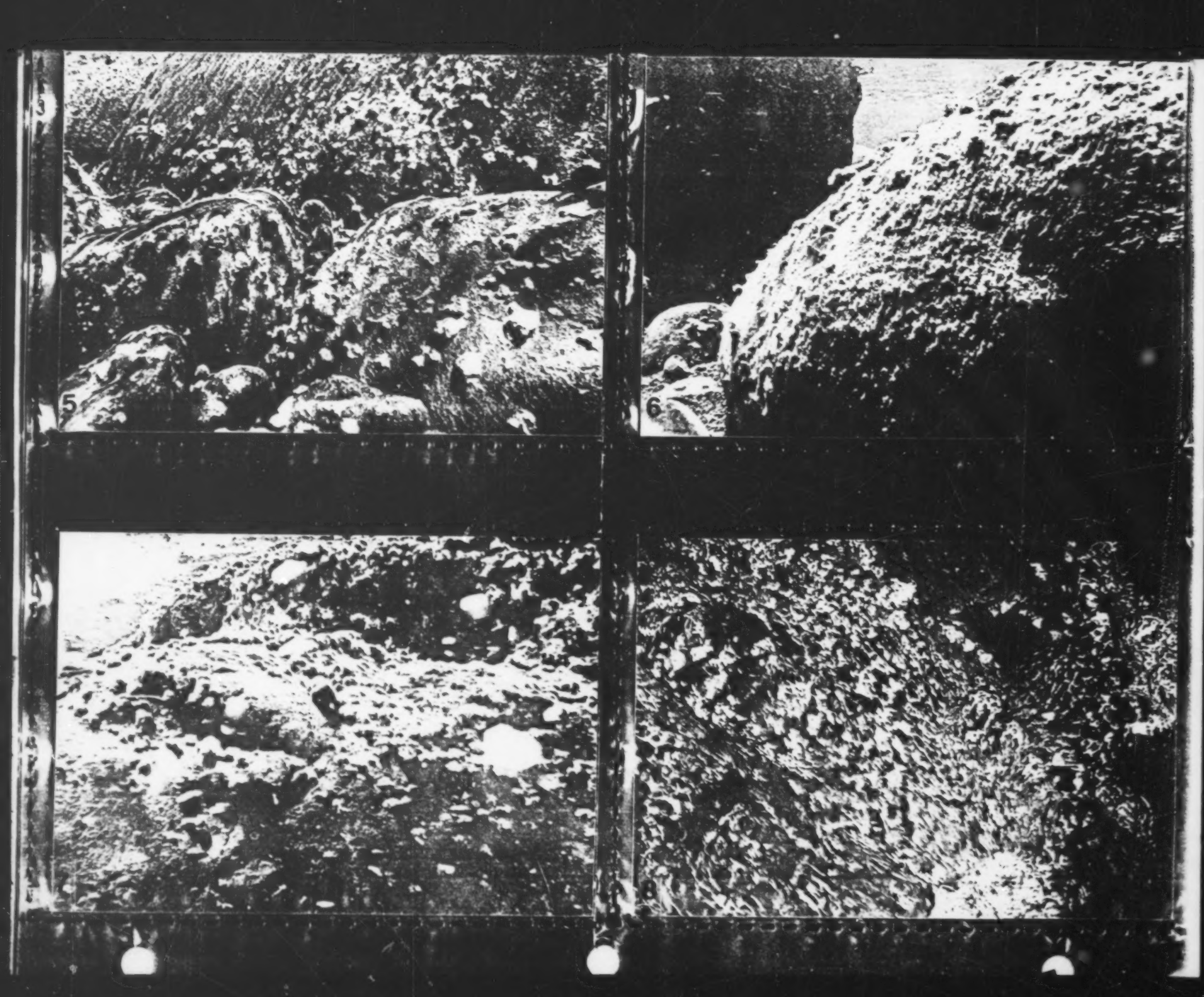
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